

100 nm

## Power Generation and Storage

# Solid-State Ultracapacitor for Improved Energy Storage

Novel, solid-state, dielectric materials design greatly enhances capacitor performance.

**NASA's Marshall Space Flight Center** has developed a solid-state ultracapacitor using a novel nanocomposite, dielectric material. The material's design is based on the internal barrier layer capacitance (IBLC) concept, and it uses novel dielectric and metallic conductive ink formulations.

Novel processing methods developed by NASA provide for unique dielectric properties at the grain level. Nanoscale raw material powders are tailored using a variety of techniques and then formulated into a special ink. This dielectric ink is used with novel metallic conductive ink to print a capacitor layer structure into any design necessary to meet a range of technical requirements.

The innovation is intended to replace current range safety batteries that NASA uses to power the systems that destroy off-course space vehicles. A solid-state design provides the needed robustness and safety for this demanding application.

## BENEFITS

- Improved safety and robustness:
  - The solid-state design eliminates liquid/gel electrolytes that can explode in extreme thermal conditions.
  - The nonpolar design leads to lower failure rates and easier implementation.
- Tunable properties for exceptional performance:
  - The dielectric voltage breakdown strength is >250 V at thicknesses <30 microns.
  - The energy storage density targets 60 J/cc, with tailorable packaging to meet board layout or circuit design parameters.
- Standard materials and processing methods for lower-cost manufacturing

technology solution



# NASA Technology Transfer Program

Bringing NASA Technology Down to Earth

## THE TECHNOLOGY

The NASA solid-state ultracapacitor technology is based on the novel materials design and processes used to make the IBLC-type ultracapacitor. The IBLC concept is known to provide outstanding capacitance behavior but has been difficult to reproduce.

NASA has developed a careful process to produce dielectric ink materials to be used in printed electronic applications with reproducibility. An individual cell is created by building electrodes on each side of the dielectric layer, and complete modules can be constructed by stacking multiple cells.

Closely related NASA innovations on dielectric and conductive ink (electrode) formulations are key to the ultracapacitor construct, and are included in the technology package.

Target performance criteria of this technology include the following:

- Use of standard materials and processing methods
- Robust solid-state device with no liquid electrolytes
- High-energy density—target energy densities of 60 J/cc at a minimum operating voltage of 50 V
- High dielectric breakdown strength (>250 V)
- Excellent pulse-power performance; rapid discharge and charge
- Reliable performance under repeated cycling (>500,000 cycles)

Additional development work is underway to build and test complete capacitor modules and to further improve material properties and performance.

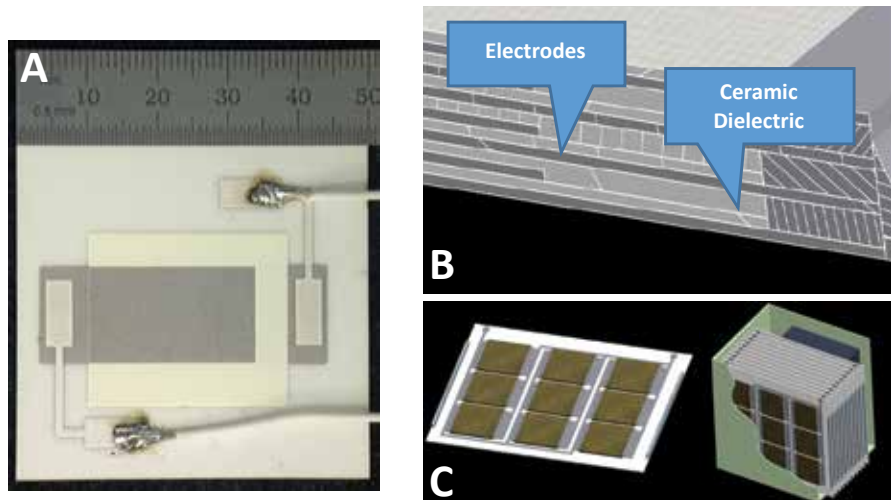


FIGURE – Methods to produce a single-layer capacitor prototype (A) are being refined to produce multilayer capacitors (B). Multilayer capacitor cells can be packaged (C) to improve capacitor energy storage.

## APPLICATIONS

The technology offers wide-ranging market applications, including:

**Aerospace** – Space power and propulsion systems

### Transportation

- Regenerative braking systems for cars, trucks, buses, and trains
- Batteries for hybrid and electric cars, as well as fuel cell-powered vehicles

**Energy** – Smart grid and renewable energy

**Defense**—Backup power supplies, laser weapons, and railguns

**Health**—Medical devices



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NASA's Technology Transfer Program pursues the widest possible applications of agency technology to benefit US citizens. Through partnerships and licensing agreements with industry, the program ensures that NASA's investments in pioneering research find secondary uses that benefit the economy, create jobs, and improve quality of life.

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